III. *An Account of the Appearance of* Mercury, *passing over the Sun's Disk, on the* 29th *of* October, 1723 *determining the mean Motion, and fixing the Nodes of that Planet's Orb.* By Edmund Halley, *LL. D. Astron. Reg. and R. S. S.*

THE Transit of the Planet *Mercury*, over the Disk of the *Sun*, being one of the most curious and uncommon Appearances that the Heavens afford, our Astronomers, both at home and abroad, made due Preparation to observe, with the utmost Exactnefs, that which happened on the 29th of *October*, 1723, which I had predicted in the Year 1691 (*Phil. Tranf.* N° 193.) would be, in Part, vifible in *England.* And the Sky proving, more than ordinary, favourable at that Time, we were enabled to obferve the Ingrefs on the *Sun*'s Limb, with the greateft Accuracy.

Accordingly, the fame Day, *Octob.* 29. *ftyl. vet.* at *Greenwich* in the *Royal Obfervatory*, I firft perceiv'd, with my 24 Foot Tube, the *Planet* making a fmall Notch in the *Sun*'s Limb at 2^h 41' 23'' *T. app.* And at 2^h 42' 26'' he was wholly enter'd, making an interiour Contact, the Light of the *Sun*'s Limb juft beginning to appear behind his dark Body; which, notwithftanding the Slownefs of the Motion, was, in a Manner, inftantaneous. Then, applying the *Micrometer* to the faid 24 Foot Tube, I open'd it fo as to take in 16' 15'' equal to the *Sun*'s Semidiameter at that time; and caufing the northern Edge of the *Sun*, to move exactly along one of the Pointers, I waited till the Center of

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Mercury came to move along the other, as I found it to
do at 3^h $1'$ $16''$ *T. app.* But *Refraction* contracting
this Difference of Declination about 5 Seconds (the
Sun being then but about $11°$ high) I concluded that
the Centers of the *Sun* and *Mercury*, were truly in the
fame Parallel of Declination at 3^h $3'$ *T. app. proxime.*

At *Wanfted* in *Effex* my worthy Collegue, the Rev.
Mr. *James Bradly, Savilian* Profeffor of *Aftronomy*,
obferv'd with the *Hugenian Telefcope*, of above 120
Foot long, the total Immerfion, or interiour Contact
of the Limbs, at 2^h $26'$ $45''$ *T. æq.* that is 2^h $42'$ $38''$
T. app. twelve Seconds later than I found it at *Green-
wich*; moft of this Difference being due to the Diffe-
rence of our Meridians. And applying the *Micrometer*
to that vaft *Radius*, he meafured the Diameter of the
Planet $10''$ $45'''$. At 2^h $48'$ $57''$ he found the Dif-
ference of Declination between the fouthern Limbs of
the *Sun* and *Planet* by the *Micrometer*, in a fifteen
Foot Tube, to be $15'$ $19''$. Wherefore, allowing the
obferv'd Semidiameter of the *Planet*, and the *Refrac-
tion*, the faid Difference was neareft $15'$ $30''$, and con-
fequently, *Mercury* more foutherly than the *Sun*'s
Center in refpect of Declination $0'$ $45''$.

Mr. *George Graham,* in *Fleet-ftreet, London*, ob-
ferv'd the firft Impreffion on the *Sun*'s Limb at 2^h $41'$
$9''$ *T. app.* and at 2^h $42'$ $19''$ *Mercury* was intirely
within the Disk. At 3^h $6'$ $41''$ he meafur'd with a *Mi-
crometer*, in a twelve Foot Tube, the Diftance of his
Center from the neareft Limb of the *Sun* $2'$ $13''$. And
again, at 3^h $25'$ $24''$ their Diftance was found $3'$ $57''$.
At 3^h $34'$ $43''$ he meafur'd the Difference of Declina-
tion, from the northern Limb of the *Sun* $14'$ $57''$,
which, corrected by *Refraction*, becomes $15'$ $4''$, that
is, $1'$ $11''$ more northerly than the *Sun*'s Center.

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In the *Obſervatory* at *Paris*, *Signor Maraldi* obſerved the firſt Appearance of *Mercury* on the *Sun's* Limb at 2^h 50′ 13″ *T. app.* and the interiour Contact at 2^h 51′ 48″. And Mr. *de Liſle*, obſerving a-part, concluded the ſame at 2^h 51′ 37″, but ſuſpects it might have been ſome few Seconds later. This Gentleman has communicated his Obſervation at large, from whence we ſhall only borrow the following obſerved Latitudes.

	h	′	″			′	″
At	2	56	20	*Latitudo Borea Mercurii*		3	36
	3	00	40			3	42
	3	10	20			3	46
	3	16	12			3	55

At *Bononia*, in *Italy*, Signor *Manfredi* obſerved *Mercury* indenting the *Sun's* Limb at 3^h 26′ 22″; and that he was gotten entirely within, at 3^h 27′ 45″. And theſe are the Obſervations moſt to be depended on, that we have receiv'd from abroad.

In order to deduce from this *Phænomenon*, ſo accurately obſerv'd, what may contribute to the Perfectioning of the Theory of *Mercury's* Motion, which (as appears by the near Agreement of our Numbers with this and many other Obſervations of him) ſeems to need but very little Correction ; I carefully computed, from our Tables, the Motion of the Planet in five Hours, and found his apparent Motion on the *Sun*, to be in Longitude 29′ 21″ Retrograde, and that his Latitude encreaſ'd northerly 4′ 17½″ in the ſame time ; whence the Horary Motion in Longitude 5′ 52″, and in Latitude 0′ 51½″, and thence the Angle of the viſible Way with the Ecliptick 8° 19′, and the Horary Motion in that Way 5′ 56″. Again, the Angle of the Ecliptick with

with the Meridian, being in this Place 73° 24', the visible Way of *Mercury*, made an Angle of 65° 5' with the Meridian passing through the Center of the *Sun*, whence the Horary Change of Declination becomes exactly 2' 30''.

These *Data* I choose rather to take from the Theory, than from immediate Observation ; because there is always an unavoidable, tho' small Uncertainty, in what we observe, yet greater than there can be in the Computation for so small a Space of Time, especially now the Theory is, as I said before, so very near the Truth.

This premised, let us now enquire the true Time of the central Ingress, and the Latitude of the Planet at that Time. And first, by my own Account, *Mercury* was gotten into the Parallel of the *Sun*'s Center, 21¼ Minutes after the central Ingress, in which Time he ascended to the *Northward* of 54'', and so much, therefore, was he more *Southerly* than the *Sun*'s Center at his Ingress. Mr. *Bradly*, 7¼ Minutes after the said Ingress, in which the Planet ascended 0' 19'', found his Declination 0' 45'' South, and therefore at the Ingress, his Declination was 1' 4'' South. And by by Mr. *Graham*'s Observation, *Mercury* was more northerly than the *Sun*'s Center 1' 11'', 53' 20'' after the central Ingress ; but in that Time, *Mercury* ascended 2' 13'', wherefore, according to him, at the Ingress the Planet had 1' 2'' South Declination. We shall not therefore err above a Semidiameter of *Mercury*, if we assume his Declination, at that Time, to have been precisely one Minute.

Now the *Sun*'s Semidiameter being then 16' 15'', one Minute is the *Sine* of 3° 32' in the Arch of the *Sun*'s Limb ; and consequently, the Point of this Ingress was 13° 4' more northerly than the Ecliptick ; whence the Latitude of *Mercury* was then 3' 40'' North, and

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Difference of Longitude 15′ 50″, by how much he, at that Time, follow'd the *Sun*'s Center.

If therefore, to the Arch of 13° 4′, we add the Double of 8° 19′, or of the Angle which the vifible Way made with the Eclipsick, we shall have 29° 42′ for the Point on the *Sun*'s weftern Limb, at which the Planet made his *Exit*, likewife to the North of the *Ecliptick*. Hence the Chord, defcrib'd in the whole Tranfit, was of 137° 14′, and the Chord itfelf 30′ 16″ ; and the nearest Diftance to the *Sun*'s Center 5′ 56″. Now the Horary Motion in this Chord, being 5′ 56″, the whole Duration of this *Mercurial Eclipfe* becomes 5ʰ 6′ in refpect of the Center of the *Planet* ; and therefore the neareft Approach of their Centers was at 5ʰ 14′ 30″ at *Greenwich*, and the *Exit* at 7ʰ 47′; both vifible in our *American Plantations*, had there been any curious Perfon there qualified to obferve them.

It follows likewife, by the obferv'd Diameter of *Mercury*, 10″ 45‴ that he was very little lefs than two Minutes of Time in pafling the Limb ; and, by the given neareft Diftance to the *Sun*'s Center, it is concluded that he was in Conjunction, in Point of Longitude, at 5ʰ 23′ 15″ having then precifely 6′ 00″ North Latitude. Nor can it be doubted, but that all this would have been found exceeding near to Truth, had not the too early fetting of the *Sun* deprived all *Europe* of the defirable Sight.

There being a very remarkable *Period* of the Motion of *Mercury* in 46 Years, in which Time, he makes 191 Revolutions about the *Sun* ; this Tranfit of ours is found to have been preceded by two others at that Interval : The firft, in the Year 1631, when *Gaffendus* at *Paris*, on the 28th Day of *October*, *ftyl. vet.* was the firft that ever obferv'd this Appearance of *Mercury* within the *Sun*'s Disk, and found him to pafs off
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at 10^h $28'$ *mane*. The fecond was, *Octob.* 28° 1677, when myfelf had the good Fortune to obferve both the Ingrefs and Egrefs of the Planet in the Ifland of *St. Helena*; the middle Time, when he was neareft to the *Sun*'s Center, being there but $3'$ $50''$ paft Noon, and the vifible Duration of the Tranfit of the Center of the Planet 5^h $14'$ $20''$; which was fome fmall matter contracted by Parallax, and moft likely might have been 5_h $15'$ $00''$ without it. Now in 5^h $15'$, *Mercury* defcrib'd the Chord of 146° $52'$ in the *Sun*'s Limb, being $31'$ $9''$, and confequently the neareft Diftance to the Center was $4'$ $38''$, or the Sine of 16° $34'$ the *Sun*'s Semidiameter being Radius; that is, $1'$ $18''$ lefs than we found it in 1723. Hence alfo it follows, that the true Conjunction in Longitude was 7 *min.* of Time later than the neareft Approach of the Centers, *viz.* at 0^h $10'$ $50''$ at St. *Helena*, or at 0^h $35'$ paft Noon at *Greenwich*: and, that the North Latitude of the Planet, at that Time, was $4'$ $41''$.

Suppofing, therefore, the neareft Diftance of the Centers in the Tranfit of 1631, to have been $3'$ $20''$, that is, $1'$ $18''$ lefs than in 1677, we fhall find that *Mercury* then defcrib'd a Chord of 156° $20'$, traverfing the Disk of the *Sun* in 5^h $21'$ $30''$; fo that fuppofing his *Exit* at 10^h $28'$ at *Paris*, that is 10^h $18'$ $40''$ at *Greenwich*, he enter'd on the *Sun* at 4^h $57'$ $10''$ in the Morning; and was neareft his Center at 7^h $38'$ *T. app.* but in the fame Longitude with him at 7^h $43'$, or *Octob.* 27° 19^h $43'$ *T. app.* having then $3'$ $22''$ North Latitude.

And here, I think I may, without Vanity, advertife the Reader, that above thirty Years fince, *viz.* in *Philofoph. Tranf.* N ^{o} 193, for the Month of *March*, *&c.* $169\frac{2}{1}$, I predicted, by Help of the two former, this laft Tranfit, with a furprifing Exactnefs,

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even beyond my Hopes, making the Time of the middle, or neareſt Approach of the Centers of the *Sun* and *Mercury*, *Anno* 1723, *Octob.* 29^d 5^h 19' *T. app*. which we found by Obſervation at 5^h 14'½, only 4'½ Minutes ſooner ; and, in Latitude, *Mercury* was but ſix Seconds more ſoutherly than I then had computed it ; the Error, in Longitude, being little more than two Diameters of this exceeding ſmall Planet ; and, in Latitude, but a ſingle Semidiameter thereof. So, that for the Future, Aſtronomers may truſt my Table of theſe Tranſits, in *Tranſact.* N° 193, to a few Minutes of Time, and not wait with the Uncertainty of Hours, nay Days, as has lately been done.

But, in order to obtain a yet further Degree of Exactneſs by Help of this Obſervation, it may be moſt expedient to compare with it the Ingreſs I obſerv'd at *St. Helena* ; becauſe, in that, as well as in this, the Latitudes of the Planet being very ſmall, a little Error in them will not ſo much affect the Longitudes. Suppoſing therefore, that *Anno* 1677, *Octob.* 27° 21^h 26' 15" at *St. Helena*, or 21^h 50' 15" *T. app.* at *Greenwich*, the Center of *Mercury* entered on the *Sun*, and that, at that Time, he was 8¼ Degrees on the *Sun*'s Limb, to the North of the Ecliptick (according to what is above concluded) it follows, that he had then 2' 20" North Latitude, and 16' 5" greater Longitude than the *Sun*'s Center; as in this preſent Tranſit, *Octob.* 29° 2^h 41' 30" *T. app.* at *Greenwich*, he had 3' 40" North Latitude, and 15' 50" more Longitude.

Now the apparent Geocentrick Differences of Longitude, are to the real Heliocentrick Differences, as the Planet's true Diſtance from the *Sun*, to his Diſtance from the *Earth* ; that is, in both Caſes, as 313 to 676; wherefore, in 1677, *Mercury* wanted 34' 45" of the Conjunction with the *Sun*; and, in 1723, but 34" 13',

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at the Times of his apparent Ingrefs on the Disk. And, equating the Times, I find, that the *Sun, Anno* 1677, *Octob.* 27^d 21^h 34' 20" *T. æq.* was, in ♏ 15° 36' 55" and, confequently *Mercury's* Heliocentrick Place ♉ 15° 2' 10": and, *Anno* 1723, *Octob.* 29^d 2^h 25' 30" *T. æq.* the *Sun* was in ♏ 16° 39' 43", and therefore *Mercury*, at that Time, in ♉ 16° 5' 30".

Mercury therefore, in 46 Years with 11 Intercalations, and befides 1^d 4^h 51' 10", has made 191 Revolutions to the Equinoctial Points, and over and above 1° 3' 20". But, by the *Scholion* to *Prop.* XIV. *Lib.* III. *Natur. Philofoph. Principia Math.* the Motion of the *Aphelion* of *Mercury*, from the Equinox in that Time, is 40' 18"; fo that there remains 23' 2" of *True Anomaly* to be reduced to the *Mean :* Now the Mean Anomaly of *Mercury*, in both Cafes, being 5 *fig.* 12°, 23' 2" of True Anomaly gives 15' 24" Mean Anomaly; which added to 40' 18" becomes 55' 42", for the Mean Motion above fo many Revolutions : and this is to be encreafed by 8" to reduce it to the Plane of *Mercury's* Orb, in all 55' 50".

Hence, doubling the Interval, in 92 *Julian* Years 1^d 9^h 42' 20", the Mean Motion of *Mercury* from the Equinox is 0^s 1° 51' 40", from which, taking 5° 44' 50" the Motion in 1^d 9^h 42' 20", we have his Motion in 92 *Julian* Years 11^s 26° 6' 50", and in 100 Years, 2^s 14° 2' 13", which is but 20" more than I had fome Years fince printed it, in my Aftronomical Tables fhortly to be publifhed, and differs but one Hour's Motion therefrom in 3000 Years.

The forementioned Proportion of the Diftances, *viz.* 313 to 676, is alfo between the Latitudes feen from the *Earth* and the Inclinations, or Heliocentrick Latitudes of the Planet : fo that 2' 20", at the Ingrefs of 1677, gives 5' 2"; and 3' 40" in 1723, becomes 7' 55"

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for the Latitudes at the *Sun.* And the Inclination of the Orb of *Mercury* to the Plane of the Ecliptick (determined by accurate Obfervations near his northern Limit) being 6° 59′ 20″, we compute the Diftance of the Planet from his Node, in the former 0° 41′ 7″, and, in the latter, 1° 4′ 37″; which, being deducted from h's Heliocentrick Places refpectively, leave the Place of the afcending Node, in 1677, ♉ 14° 21′ 3″; and, in 1723, ♉ 15° 0′ 53″: So, that in 46 Years the Node is found 39′ 50″ forwarder in the Ecliptick; which is but 1′ 30″ more than the Præceffion of the Equinox in the fame Time. We may therefore fafely affume the Plane of the Orb of *Mercury* to be immoveable in the Sphere of fix'd Stars, and its afcending Node to be ♋ 15° 41′ from the *firft Star of* Aries. Nor can fo very flow a Motion (fuppofing fuch to be) be fully defined, but by the utmoft Care and Diligence of future Aftronomers, after the Obfervation of many Ages.

As to the reft of the Theory of this Planet's Motion, I make his mean Diftance from the *Sun,* 38710 fuch Parts as the mean Diftance of the *Sun* and *Earth* is 100000; and his greateft Equation 23° 42′ 37″. The *Epocha* of his middle Motion, *ineunte Anno* 1723, *ftyl. vet.* from the Equinoctial Point, I make ♐ 19° 9′ 31″; and that of his Aphelion to the fame Time ♐ 13° 3′ 34″: the Aphelion moving *fecundum Seriem Signorum,* feven Minutes in eight Years. And thefe Numbers I prefume, may reprefent the Motion of *Mercury,* with an Exactnefs equal to that of any of the other Planets; perhaps as near as the *Sun's* Place by any Tables, or thofe of the fixed Stars by any Catalogue yet extant.

It were to be wifhed, that fome good Obfervation, like this, had been made of the like Tranfit of *Mercury* at his other Node in *April,* where he was feen indeed

deed *April* 23° 1661, but fo imperfectly, that neither Ingrefs nor Egrefs was any where obferv'd ; and, though it be certain, that he traverfed the *Sun* on *April* 26°, 1674 ; and again *April* 24, 1707, yet we were fo unfortunate, that the Conjunction in both happened fo near Midnight, that he efcaped unfeen by all the Aftronomers of *Europe*, excepting fingly Mr. *Roemer* at *Copenhagen*, whofe Obfervation I have lately received by the Favour of Mr. *De l' Ifle* the Aftronomer, communicated in the Words of the Manufcript Journal of Obfervations of the faid Mr. *Roemer*.
" *Hodie fexto Maii* (*Anno* 1707) *hora matutina*
" 4^h 19', *fpectabatur Mercurius in extremo margine*
" *Solis jamjam exiturus*; *altus fupra imum folis*
" *marginem ¼ diametri folaris*, & *ad finiftram in*
" *Tubo* (*fc. invertente*) *Accuratius hæc determi-*
" *nare non licuit ob moram nimis brevem*." It was great Pity, that he did not, at leaft, eftimate, how many Diameters of his Body he was diftant from the Limb of the *Sun*, or what Part of a Diameter, if fo near : But having examined this Obfervation, I find that the *Sun*, at that Time, was but juft rifen, or rather rifing, and foon after entered into a Cloud, fo that the Limb of the *Sun* could not be diftinctly feen, it always undulating and fparkling much, when fo near the Horizon ; in which Circumftance, a juft Obfervation could hardly be made.

Let us now fee how our Numbers, corrected as above, will reprefent this Obfervation. *Anno* 1707, *April* 24° 16^h 19' at *Copenhagen* is 15^h 28' at *Greenwich*, but 15^h 24 20" *T. æq.* To this Time, I find the *Sun's* true Place ♉ 14° 50' 1", and his Diftance from the *Earth* 101005. The correct *Epocha* of *Mercury's* mean Motion, for the Year 1707, is 3^s 13° 18' 45", to which adding, for the reft of the Time, 3^s 19° 9' 28",

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we shall have his middle Motion at the Time of the Observation ♏ 2° 28′ 13″ ; and, taking his *Aphelion* in ♐ 12° 49′ 49″ therefrom, we have his mean Anomaly 10ˢ 19° 38′ 24″, and thereby the Equation to be added 12° 39′ 41″, and thence the Place of *Mercury* in his Orb ♏ 15° 7′ 54″. But the correct Place of the descending Node is ♏ 14° 46′ 25″, and therefore *Mercury*, being 21′ 29″ past the Node, had 2′ 36″ South Latitude at the *Sun* ; and his Place, reduced to the Ecliptick, was ♏ 15° 7′ 45″, that is, 17′ 44″ past the Conjunction of the *Sun*, which diminished in the Proportion of 5567 to 4533, or of the Distance of the Planet from the *Earth* to his Distance from the *Sun*, becomes 14′ 27″ ; and by so much was he past the Conjunction as viewed from the *Earth*. Again, by the same Proportion, his Geocentrick Latitude, at that Time, was 2′ 7″ South ; and therefore, his apparent Distance from the *Sun*'s Center, was 14′ 37″ ; that is, but 1′ 18″ from his western Limb ; so that he might well be said to be, *jamjam exiturus.*

But, that *Mercury* should at that Time be so far northerly, as Mr. *Roemer*'s Words import, was absolutely impossible ; and, I am apt to believe, that so acute an Astronomer as Mr. *Roemer* was, could not himself be the Observer, but some Person less acquainted with these Matters ; which the Words *spectabatur Mercurius*, instead of *Mercurium vidi*, seem to import. If he had then had North Latitude, he must needs have been seen in the *Sun* in *April* 1720, which we are assured he was not.

Lastly, it may not be amiss to advertise, that on the last Day of *October* 1736, *Mercury* will again traverse the northern Part of the *Sun*'s Disk, both Ingress and Egress being visible to all *Europe*.

F I N I S.